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A Review of *Microhydromys* (Rodentia: Murinae), with Description of a New Species from Southern New Guinea

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ABSTRACT

The murine rodent genus *Microhydromys* Tate and Archbold, 1941, includes the smallest of the native rodents of New Guinea and is the rarest Australo-Papuan rodent genus preserved in world museums. We discuss the morphological characteristics of *Microhydromys* and diagnose two species in the genus: *M. richardsoni* Tate and Archbold, 1941, distributed over northern New Guinea, and *M. argenteus*, n. sp., recorded from three localities in southern New Guinea. The only other species previously classified in the genus—*Microhydromys musseri* Flannery, 1989—is re-allocated to the genus *Pseudohydromys* Rümmler, 1934. The little available information relating to their biology indicates the species of *Microhydromys* to be terrestrial inhabitants of foothill and lower montane forest formations and probably naturally rare in those environments.

INTRODUCTION

The amphibious “water-rats” and terrestrial “moss-mice” of Australia and New Guinea comprise a distinctive group of nine murine genera endemic to the Australo-Papuan region

(*Hydromys* E. Geoffroy, 1804, *Parahydromys* Poche, 1906, *Crossomys* Thomas, 1907, *Baiyankamys* Hinton, 1943, *Xeromys* Thomas, 1889, *Leptomys* Thomas, 1897, *Paraleptomys* Tate and Archbold, 1941, *Pseudohydromys* Rümmler, 1934, and *Microhydromys* Tate and

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Archbold, 1941). All of these genera occur on the island of New Guinea, with *Hydromys* and *Xeromys* found also in Australia (Flannery, 1995; Hitchcock, 1998). Though they span a great range of body sizes, habits, and ecologies, because of similar derivations in craniodental anatomy they have long been regarded as a natural (monophyletic) group (e.g., Rümmler, 1934, 1938; Tate, 1951; Laurie and Hill, 1954; Lidicker, 1968, 1973; Menzies and Dennis, 1979; Flannery, 1995; Helgen, 2005b; cf. Breed and Aplin, 1994; Watts and Baverstock, 1994, 1996), a point recently confirmed by a molecular genetic study of mitochondrial and nuclear gene sequence data from a broad array of Old World murine rodents (Rowe et al., 2008). As such, these genera together constitute an outstanding endemic Australo-Papuan adaptive radiation that has received minimal study. The appropriate taxonomic rank of this group of rodents requires further consideration; under current classification schemes, this group could be recognized under a single "Division" (sensu Musser and Carleton, 2005) or perhaps as a subtribe, Hydromyina, within a more expansive tribe of Australo-Papuan rodents classified as the Hydromyini (Breed and Aplin, 1994; Watts and Baverstock, 1994, 1996; Rowe et al., 2008). Here we employ the subtribal descriptor "hydromyinan" as a precise (if cumbersome) designation for members of this diverse but monophyletic suite of rats and mice.

With a few honorable exceptions (Mahoney, 1968; Musser and Piik, 1982; Flannery, 1989), very little taxonomic work has been focused on hydromyinans in the half century since the publication of Tate's (1951) magnum opus on the systematics of Australo-Papuan murines and the landmark review of Wallacean and Melanesian mammal systematics published by Laurie and Hill (1954). This is now changing. Recent publications have provided comprehensive taxonomic reviews of *Baiyankamys* (Helgen, 2005b), *Leptomys* (Musser et al., 2008), and *Pseudohydromys* (Helgen and Helgen, 2009); including the nominal genera *Mayermys* Laurie and Hill, 1954 and *Neohydromys* Laurie, 1952—see Musser and Carleton, 2005), and revisions of *Paraleptomys* and *Hydromys* are in progress by Helgen and collaborators. The number of hydromyinan species documented in these

revisionary works more than doubles the number of species recognized by current faunal reviews and taxonomic compendia (i.e., Flannery, 1995; Musser and Carleton, 2005). The present contribution is a revision of *Microhydromys* Tate and Archbold, 1941, the aim of which is to document the diagnostic attributes, taxonomic content, and geographic distribution of the genus.

Two species have previously been recognized in *Microhydromys*—*M. richardsoni* Tate and Archbold, 1941, and *M. musseri* Flannery, 1989 (Flannery, 1990, 1995; Musser and Carleton, 1993, 2005). The type species of *Microhydromys*, *M. richardsoni*, was described on the basis of a single specimen collected in the Mamberamo Basin, on the northern slopes of New Guinea's expansive Central Cordillera, during the Third Archbold Expedition to New Guinea (Tate and Archbold, 1941; Archbold et al., 1942). Three decades would pass before any additional samples referable to *M. richardsoni* were collected, and no specimens apart from the holotype were discussed in the literature until 1979, when Menzies and Dennis (1979: 55), after a review of global museum holdings, observed that "the very few records of this species are all in hill forest ranging from Sogeri in the SE to central Irian Jaya, but at lower altitudes than the other 'moss mice,'" and George (1979: 95) wrote that "*Microhydromys richardsoni* has only been collected on three occasions from widely separated localities in lowland New Guinea."

Flannery (1989) provided the only revision of the genus *Microhydromys* to date, produced within the context of describing a new species, *Microhydromys musseri*. In his review of the genus, Flannery (1989) discussed the single known specimen of *M. musseri* and documented a total of four museum specimens referable to *M. richardsoni*; in a later publication (his revised *Mammals of New Guinea*), he discussed one additional specimen referred to *M. richardsoni* (Flannery, 1995).

We have recently revisited and studied all museum specimens previously referred to *Microhydromys*, collected one additional modern specimen of *Microhydromys* in southern Papua New Guinea, and discovered a subfossil jaw referable to *Microhydromys* in a

Holocene cave deposit in northern Papua New Guinea. We draw on this material to define and diagnose the genus *Microhydromys*, argue that “*Microhydromys*” *musseri* is more appropriately referred to the genus *Pseudohydromys*, and describe a new species of *Microhydromys*. Our contribution is purely alpha taxonomic in scope; pending ongoing molecular studies, we do not defend or review the precise phylogenetic relationships of *Microhydromys* among hydromyines and within the broader context of endemic of Australo-Papuan murines (Rowe et al., 2008). Instead, we focus on documenting relevant morphological, environmental, and distributional aspects of the genus. This is our intention for *Microhydromys*, just as it was in recent generic-level overviews of *Baiyankamys* (Helgen, 2005b), *Leptomys* (Musser et al., 2008), and *Pseudohydromys* (Helgen and Helgen, 2009), and will be for future reports. In our view, this approach takes priority at the present time because it is this taxic level that is currently most underestimated in New Guinea mammals (Helgen, 2007), and because taxonomic overviews are ideally requisite to direct future studies aimed toward better discerning, refining, and testing mammalian patterns of historical biogeography, phylogenetic and ecomorphological diversification, and conservation prioritization in the Melanesian region (e.g., Flannery, 1995; Heads, 2001, 2002, Amori et al., 2008; Schipper et al., 2008).

MATERIALS AND METHODS

Specimens discussed here are deposited in the collections of the Australian Museum, Sydney (AM); the American Museum of Natural History, New York (AMNH); the Australian National Wildlife Collection, Canberra (ANWC); and the Bernice P. Bishop Museum, Honolulu (BBM-NG).

Anatomical terminology follows Brown (1971) and Brown and Yalden (1973) for external features of the head and limbs; Wahlert (1985) for the cranial foramina; and Carleton (1980), Musser and Heaney (1992), and Musser et al. (1998) for cranial morphology.

Values (in mm) for total length and length of tail are those recorded by collectors on labels attached to skins. Subtracting length of tail (abbreviated TV) from total length pro-

duced a value for length of head and body (HB). Values for length of hind foot (HF), which includes claws, were either obtained from skin labels or from our measurements of dry study skins; those for length of ear (E) come from collector’s measurements recorded on skin labels or in field journals (we assume, but are not certain for all specimens, that ear length measurements represent the greatest length from the notch to the distal margin of the pinna).

We used digital calipers to measure (and record to the nearest 0.01 mm) the following cranial and dental dimensions, under a magnifying lens when necessary (see table 1):

CIL	condyloincisive length
ZB	zygomatic breadth
POB	postorbital breadth
BBC	breadth of braincase
HBC	height of braincase
LN	length of nasals
LD	length of diastema
PL	palatal length
LBP	length of bony palate (palatal bridge)
BBP	breadth across bony palate at second molars
BMF	breadth of mesopterygoid fossa
BIT	breadth across upper incisors at tips
BIR	breadth across upper incisors at roots
BR	breadth of rostrum
LB	length of bulla
LIF	length of incisive foramina
CLM	crown length of maxillary molar row
LM1	length of first upper molar (crown)
BM1	breadth of first upper molar (crown)
BM2	breadth of second upper molar (crown)

Limits of these measurements are defined by Musser and Newcomb (1983), Voss (1988), and Musser et al. (2008). Molars were measured across their crowns.

GAZETTEER

Place names and altitudes were taken from skin tags or published expedition summaries. Bonaccorso (1998), Flannery (1995), Laurie and Hill (1954), Leary and Seri (1997), and Taylor et al. (1982) were the sources most commonly consulted for geographic coordinates. The number preceding each place corresponds to the same numbered locality on the map in figure 1. We personally examined and identified all the specimens,

TABLE 1
Selected details and measurements for the six specimens of *Microhydromys*

Museum Number Locality Elevation (m)	<i>M. richardsoni</i>			<i>M. argenteus</i> , n. sp.						
	AMNH 152079 Idenburg 850	BBM-NG 105289 Telefomin 1500	AMNH 198790 Adelbert 670	BBM-NG 60202 Sogeri 550	AM M14166 Mt. Sisa 1450	UPNG 4310 Darai 380	Mean	SD	Mean	SD
HB	83	79	83	81.7	2.31	86	86	78	83.3	4.62
TV	92	84	84	86.7	4.62	83	79	71	77.7	6.11
TV/HB (%)	111%	106%	101%	106%		95%	92%	91%	93%	
HF	20	17	19	18.7	1.53	19	19.5	22	20.2	1.61
E	8	12	11	10.3	2.08	12	11.4	13	12.1	0.81
Mass	—	11	—	11	—	—	12	13	12.5	—
CIL	—	19.1	ca. 19.7	19.4	—	19.4	20.4	—	19.9	—
ZYG	—	9.3	ca. 9.3	9.3	—	9.5	10.1	—	9.8	—
POB	4.4	4.3	4.1	4.3	0.12	4.2	4.7	—	4.4	—
BBC	—	9.1	—	9.1	—	9.2	9.8	—	9.5	—
HBC	—	6.3	—	6.3	—	6.4	6.5	—	6.4	—
LN	6.3	5.2	6.3	5.9	0.66	5.9	7.0	—	6.4	—
LD	5.1	5.3	5.8	5.4	0.35	5.3	6.2	—	5.7	—
PL	—	—	8.5	8.5	—	—	8.4	—	8.4	—
LBP	—	4.0	4.8	4.4	—	4.7	4.6	—	4.7	—
BBP	2.8	2.6	2.5	2.6	0.15	2.7	2.8	—	2.8	—
BMF	—	1.4	ca. 1.6	1.5	—	1.4	1.5	—	1.5	—
BIT	1.1	1.2	1.3	1.2	0.08	1.3	1.4	—	1.3	—
BIR	1.9	1.9	1.9	1.9	0.02	2.0	2.0	—	2.0	—
BR	4.3	4.1	4.2	4.2	0.15	4.0	4.2	—	4.1	—
LB	—	3.7	—	3.7	—	3.8	4.1	—	4.0	—
LIF	2.4	1.9	2.2	2.2	0.24	1.8	1.9	—	1.8	—
CLM	2.0	2.0	2.0	2.1	0.23	1.9	2.1	—	2.0	—
LM1	1.6	1.4	1.4	1.5	0.15	1.4	1.4	—	1.4	—
BM1	0.8	0.8	0.7	0.8	0.05	0.7	0.8	—	0.7	—
BM2	0.7	0.6	0.6	0.7	0.05	0.6	0.6	—	0.6	—

which to our knowledge comprise all available examples of *Microhydromys* in the collections of the world's natural history museums.

Microhydromys richardsoni Tate and Archbold, 1941 (4 localities)

1. Indonesia, Papua Province: 4 km southwest of Bernhard Camp on the Idenburg River (circa 03°30'S, 139°12'E), 850 m, Araucaria Creek, Sahoweri River, Mamberamo Basin, northern slopes of the Snow Mountains (AMNH 152079, skin and skull). See Tate and Archbold (1941), Brass (1941), and Archbold et al. (1942) and below for detailed discussion of this locality. This is the type locality of *M. richardsoni*.
2. Papua New Guinea, West Sepik (= Sandaun) Province: Paleflatu Cave (circa 02°37'S 141°01'E), 20 m, 5 km east of Wutung Village, northern margin of Oenake Range (ANWC CM29994, subfossil maxilla).
3. Papua New Guinea, West Sepik (= Sandaun) Province: Telefomin (05°10'S, 141°43'E), 1500 m, Star Mountains (BBM-NG 105829, skin, skull, and postcranial skeleton). The mammal fauna of the vicinity of Telefomin was reviewed in detail by Flannery and Seri (1990).
4. Papua New Guinea, Madang Province: Wanuma (04°54'S, 145°19'E), 7 km south of Atitau, Adelbert Range, 2200 feet (= 671 m) (AMNH 198790, skin and skull).

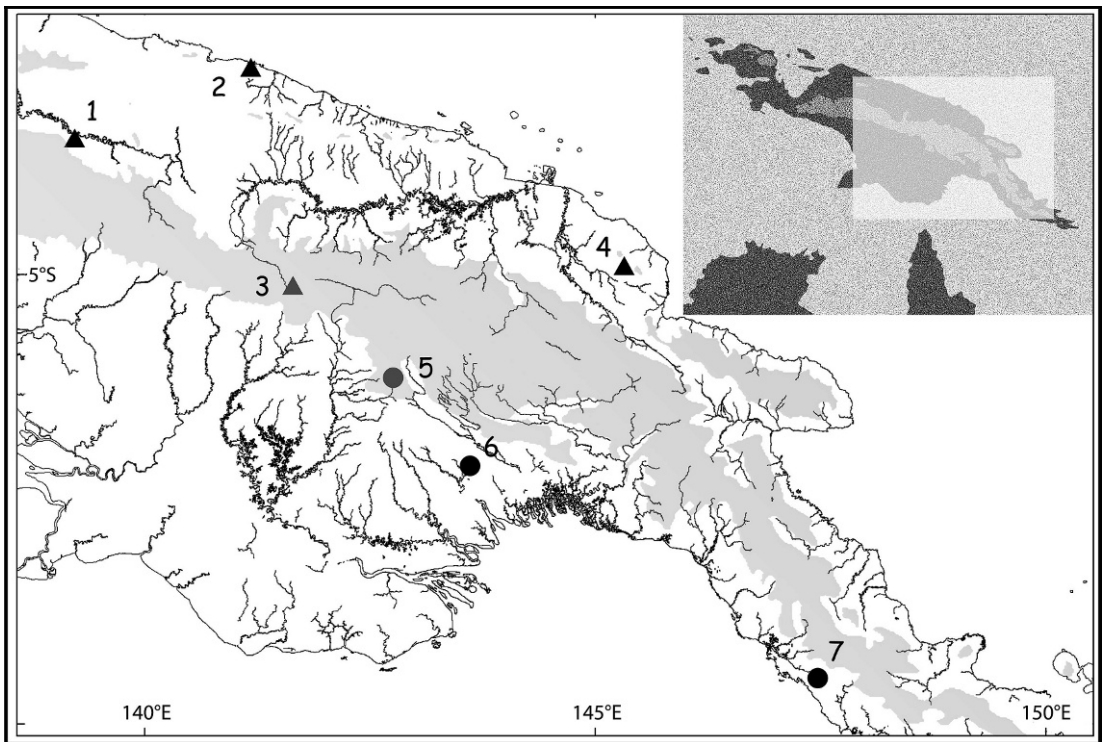


Fig. 1. Map of New Guinea, showing recorded localities (see Gazetteer) for *Microhydromys richardsoni* (triangles) and *M. argenteus*, n. sp. (dots). Shaded areas represent the areas above 1000 m elevation.

Microhydromys argenteus, n. sp. (3 localities)

5. Papua New Guinea, Southern Highlands Province: Mt. Sisa (= Mt. Haliago, circa 06°09'S, 142°45'E), southern slopes, 1450 m (AM M14166, skin and skull). Dwyer (1990) and Leary and Seri (1997) provided a map and other relevant information for Mount Sisa; see also Dwyer (1983, 1984) and Plowman (1983) for commentary regarding this site's ecological context.
6. Papua New Guinea, Gulf Province: 10 km northeast of the village of Faia (7°08'S, 143°37'E), 380 m, Darai Plateau (UPNG 4310, fluid specimen). See below and Leary (2004) for more detailed discussion about this site.
7. Papua New Guinea, Central Province: Sirinumu Dam (Lake Sirinumu), 550 m, Sogeri Plateau (BBM-NG 60202, skin and skull). This is the type locality of *M. argenteus*, n. sp. Lake Sirinumu is a manmade reservoir (Chambers, 1987); for

other information on the area see also Aplin et al. (in review) and Berra et al. (1975).

SYSTEMATICS

Microhydromys Tate and Archbold, 1941

TYPE SPECIES AND CONTENT

The type species of *Microhydromys* is *M. richardsoni* Tate and Archbold, 1941. Natural history museums currently hold material of one additional species, described here as *M. argenteus*, n. sp. (figs. 2–4).

"*Microhydromys*" *musseri* Flannery, 1989 (fig. 5) is a distinctive moss-mouse species known from a single specimen collected in mossy upper montane forest on Mt. Somoro in the Torricelli Mountains (part of Papua New Guinea's North Coastal Range). Flannery (1989) originally described this



Fig. 2. Skins of *M. argenteus*, n. sp. (A, B, holotype: BBM-NG 60202, adult male, Sogeri Plateau) and *Microhydromys richardsoni* (A', B': BBM-NG 105829, adult female, Telefomin).

species within *Microhydromys*, a genus previously known only by the type species, *M. richardsoni*, but did not provide a redefinition of the genus to accommodate this decision.

Ziegler (1982: 883) had initially identified this taxon (*musseri*) as "*Pseudohydromys* (undescribed species)," and subsequent reviewers have queried its placement in *Microhydromys*



Fig. 3. Skulls of *Microhydromys argenteus*, n. sp., left (holotype: BBM-NG 60202, adult male, Sogeri Plateau), and *M. richardsoni*, right (BBM-NG 105829, adult female, Telefomin).

(Musser and Carleton, 1993, 2005; Helgen, 2005b). Certainly, “*Microhydromys*” *musseri* lacks the most conspicuous (and synapomorphic within the context of Australo-

Papuan murines) features that characterize both *M. richardsoni* and *M. argenteus*, n. sp.—extremely small size (condyloincisive length ≤ 20.5) and longitudinally grooved upper inci-

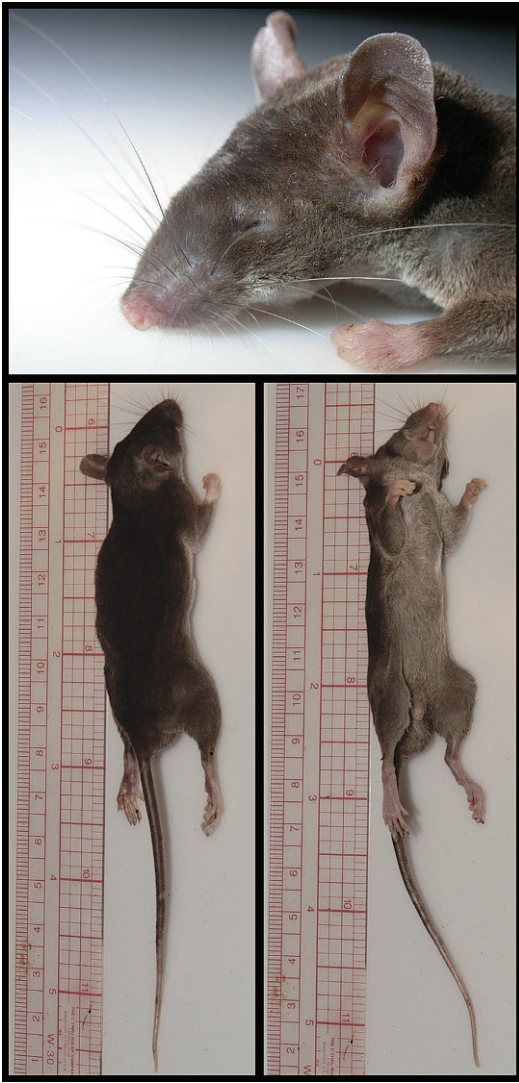


Fig. 4. Above, head of *Microhydromys argenteus*, n. sp. (UPNG 4310), from the Darai Plateau, taken in the field, photograph by Michael Pennay. Below, body of the same, dorsal (left) and ventral (right) views, photographs by Allen Allison. Image of head (above) previously figured by Leary and Mamu (2004) as “*Microhydromys richardsoni*.”

sors. On the other hand, it shares several derived traits with the species of *Pseudohydromys* (including *Neohydromys* and *Mayermys*) to the exclusion of *M. richardsoni* and *M. argenteus*, n. sp., including reduced auditory bullae, a distinctively shortened interparietal bone, and a derived pattern of



Fig. 5. Skull of the holotype and only known specimen of *Pseudohydromys musseri* (Flannery, 1989) (BBM-NG 101737, Mt. Somoro, Torricelli Mountains), originally described as a species of *Microhydromys* (Flannery, 1989; Helgen and Helgen, 2009). Scale bar = 1 cm.

cephalic arterial circulation as reflected by the size and configuration of foramina in the basicranial region (for assessments of polarity cf. Musser, 1982, 1987; Musser and Heaney, 1992; Helgen and Helgen, 2009). It also bears an intimate craniometric resemblance to certain species of *Pseudohydromys*, as documented by multivariate morphometric comparisons (Helgen and Helgen, 2009), rather than to *Microhydromys* spp. or any other hydromyinan taxa. As Helgen and Helgen (2009) note, “In combination ... these morphometric and qualitative morphological comparisons reject

a sister relationship between *musseri* and the species of *Microhydromys* and suggest instead that *musseri* is more appropriately recognized as a member of *Pseudohydromys*.”

DIAGNOSIS AND DESCRIPTIVE NOTES

The species of *Microhydromys* can be distinguished from all other murines by the following combination of characters: (1) very small body and cranial size, with condyloincisive length measuring ≤ 20.5 mm; (2) short, soft, blackish or grayish pelage; (3) a dark tail with a pale tail tip, slightly shorter to slightly longer than the head and body; (4) orthodont upper incisors, each marked by a distinct longitudinal groove “separating [the] anterior face of [the] tooth into an outer third and an inner two-thirds” (Tate and Archbold, 1941: 2), a trait unique among Australo-Papuan murine genera; (5) two relatively small molars in each quadrant of the jaw (i.e., M1/m1 and M2/m2), all with “basin”-shaped surfaces (i.e., with occlusal topography extremely similar to that in *Hydromys* and *Baiyankamys*—e.g., see pictures in Musser and Heaney, 1992; Misonne, 1969); (6) a basic cranial conformation denoted by weakly expanded zygomata, a short and rather blunt rostrum featuring nasals that protrude sharply over the premaxillae to overhang the upper incisors, short subparallel incisive foramina, a broad and high braincase sloping sharply but linearly downward from crown to nasals, a weakly constricted interorbital region, and relatively large auditory bullae; (7) osseous reflections in the basicranium (e.g., a large stapedial foramen and short groove in the ventral surface of the pterygoid plate in which the infraorbital branch of the stapedial artery courses) indicating retention of the plesiomorphic murine cephalic arterial pattern (see diagrams in Musser and Heaney, 1992; Musser et al., 1998); (8) a gracile dentary with long and slender incisors, tiny molars, a tiny coronoid process, and slender condyloid and angular processes; and (9) small, unspecialized feet (with plantar and palmar surfaces bearing the usual complement of pads—four metacarpal pads, a thenar, and smaller hypothenar on the forefoot; conspicuous interdigital pads, large thenar, and small hypothenar on the hind

feet), without extensive interdigital webbing—denoting terrestrial habits (cf. Tate and Archbold, 1941; Helgen and Helgen, 2009) and without excessively elongate hind feet (e.g., as seen in the partly saltatorial hydromyinan genera *Leptomys* and *Paraleptomys*; Musser et al., 2008).

The number of teats in *Microhydromys* is not previously recorded in the literature (Flannery, 1995) in part because the first three specimens of *Microhydromys* to be collected were male (Tate and Archbold, 1941; Flannery, 1989). Only two females have ever been collected. Peter Dwyer’s field notes (original copy held at ANWC) for AM M14166, a female of *M. argenteus*, n. sp., from Mt. Sisa, includes the comment “tts med – 0 + 2, perf” which signifies moderately prominent teats, with pectoral and abdominal teats absent, two inguinal teats present on each side, and a perforate vagina. (The skin of this specimen is preserved as a flat preparation and the teats are no longer apparent.) A female specimen of *M. richardsoni* from Telefomin (BBM-NG 105829) includes a well-prepared study skin. The accompanying skin label notes that the animal was lactating when captured but does not record the mammary formula. Two pairs of inguinal teats are clearly apparent on the study skin, and there is a faint indication of a pair of axillary teats (probably nonfunctional if truly present). We suspect that the typical mammary conformation for both species of *Microhydromys*, as for most hydromyinanans (Helgen and Helgen, 2009), is two pairs of inguinal teats.

Microhydromys richardsoni Tate and Archbold, 1941

TYPE MATERIAL AND LOCALITY: The holotype of *richardsoni* is AMNH 152079, adult male, skin and skull, from “four kilometers southwest of” Bernhard Camp on the Idenburg River (03°29’S, 139°13’E, Papua Province, Indonesia), 850 m, northern slopes of the Snow Mountains, collected 16 March 1939 by W.B. Richardson (Tate and Archbold, 1941; Tate, 1951; Lawrence, 1993). This expedition camp (“four kilometers southwest of Bernhard Camp”) was erected on the bank of what expedition members designated as “Araucaria Creek,” a tributary of the

Sahoeweri River (Archbold et al., 1942). The camp was "situated in a shut-in valley behind the fronting ridge of the mountains that rise from the Mervlakte" (Archbold et al., 1942: 239). This spot is depicted in a photograph in figure 2 of plate 11 in Archbold et al. (1942), reproduced here as figure 6; also see the description published by Brass (1941). A photograph of rain forest in the vicinity (900 m) was figured by Brass (1941: pl. 5, fig. 2), reproduced here as figure 7. It took expedition members about four hours or so to trek from "Bernard Camp" to the 850 m locality (and the habitats are very different between the two camps; Brass, 1941).

DIAGNOSIS: *Microhydromys richardsoni* differs externally from *M. argenteus*, n. sp., in having darker grayish-black pelage, both dorsally and ventrally, sometimes with white flecking on the belly (paler, uniformly gray-brown fur, above and below, in *M. argenteus*, n. sp.: fig. 2); a proportionally longer tail, measuring 101%–111% of head-body length (91%–95% of head-body length in *M. argenteus*, n. sp.: table 1); a short discrete white tail tip, less than one-quarter of tail length, without extensive mottling (versus a long pale terminal tip, measuring at least one-third of total tail length, with pale mottling extending beyond, to at least to the midpoint of the tail on the dorsal and ventral surfaces, in *M. argenteus*, n. sp.); and slightly shorter hind feet and pinnae (table 1). Compared to *M. argenteus*, n. sp., the skull of *M. richardsoni* has proportionally narrower zygomata, narrower incisors, slightly wider molars, longer incisive foramina, and smaller auditory bullae. We recommend the English common name "northern groove-toothed moss-mouse" for this species.

DISTRIBUTION AND NATURAL HISTORY: *Microhydromys richardsoni* is known from three modern specimens collected at three localities scattered in the foothills and lower montane forests in northern New Guinea. Two specimens have been taken on the northern margin of the Central Cordillera—one from 850 m on the Sahoeweri River, situated on the slopes of the Snow Mountains in the Mamberamo Basin (the type locality), the other at 1500 m at Telefomin in the Star Mountains. One additional specimen derives from middle-elevation forests (670 m) at Wanuma in the outlying Adelbert Range of

northeastern New Guinea. The mean elevation of these three trapping sites is 1007 m.

A fourth specimen, an isolated subfossil maxilla with M1–2, has been collected by K. Aplin in the Oenake Range, a mountain block near the Bewani Mountains that is part of the outlying North Coastal Range (fig. 8; measurements for this specimen include: breadth of the zygomatic plate, 1.13 mm; CLM (M1–2) 2.30 mm; length \times width of M1, 1.57 mm \times 0.86 mm; length \times width of M2, 0.83 mm \times 0.71 mm). The Oenake Range specimen is part of a large assemblage of small vertebrate bones taken from a 1 m deep sequence of bone-rich sediments in Paleflatu Cave, located in an uplifted coralline limestone terrace close to the present coastline and no more than 30 m above sea level. The bone accumulation is attributed to long-term use of the cave by owls (of uncertain taxonomic identity) through the mid- to late Holocene (as indicated by C^{14} dating; K. Aplin et al., unpublished data). Though the cave appeared to be unoccupied by owls in 2005, the presence on the surface of partially disaggregated pellets suggests a recent to contemporary age for remains lying on the surface of the deposit. To date, only one specimen of *M. richardsoni* has been identified in the assemblage, and this comes from the surface layer.

Together, these four records of occurrence (three modern, one subfossil) establish that *M. richardsoni* is widely distributed in northern New Guinea, and indicate an ecological association with forests situated on mountain slopes down to low elevation. Though captures of *M. richardsoni* are rare, like Tate (1951: 225) we expect that this species occurs along the length of the northern face of the expansive Central Cordillera. The records from the Adelbert and North Coastal Ranges suggest further that it is likely to occur in foothill forests in other northern New Guinea outlying ranges, such as the Foja and Cyclops Mountains of western New Guinea and the mountain ranges of Papua New Guinea's Huon Peninsula. It remains to be established whether, in addition to mountain slope habitats, *M. richardsoni* inhabits the expansive rainforested lowlands of northern New Guinea (principally comprising the Sepik-Ramu and Mamberamo-Idenburg-



Fig. 6. “Expedition camp in flood plain rain-forest at 850 m. on Araucaria Creek, four kilometers southwest of Bernhard Camp” (Brass, 1941: 342). The holotype of *M. richardsoni* was collected while the 1938–1939 Archbold Expedition was stationed at this camp. Photograph previously figured by Brass (1941: pl. 6, fig. 1) and Archbold et al. (1942: pl. 11, fig. 2) and reproduced from the Archbold archives.

Rouffaer drainage basins) that isolate the outlying mountain ranges of northern New Guinea from the extensive montane rain forests of the Central Cordillera.

Almost nothing is known of the natural history of *M. richardsoni*. All three known specimens were snap-trapped, presumably on the ground. A label accompanying the Wanuma specimen notes that it was collected in “second growth,” but no explicit habitat notes accompany the holotype, or the specimen from Telefomin. Flannery and Seri (1990)

provided a good account of local habitats in the vicinity of Telefomin, where one of the three modern specimens was trapped (Ziegler, 1989). Though Tate and Archbold (1941) did not record the exact context of collection for the holotype, Archbold et al. (1942: 239–243) and Brass (1941) described in detail the forests along the flood plain of Araucaria Creek and on adjacent ridges around the 850 m camp station at which the holotype of *M. richardsoni* was collected, capturing a range of forest formations from flood plain to ridges.



Fig. 7. Mossy *Nothofagus* rain forest in the immediate vicinity of the type locality of *Microhydromys richardsoni*—4 km southwest of Bernhard Camp, 900 m (see text). Photograph previously figured by Brass (1941: pl. 5, fig. 2) and reproduced from the Archbold archives courtesy of Darrin Lunde.

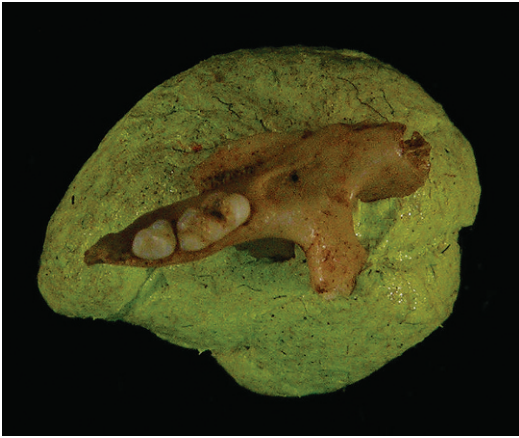


Fig. 8. An isolated maxilla of *Microhydromys richardsoni* with M^{1-2} (ANWC CM29994) from the Oenake Range, West Sepik Province, Papua New Guinea, in ventral view (CLM [M1–2] = 2.30 mm).

According to Brass (1941: 289–290), this station lay beyond a 900 m ridge

in a mountain-locked valley dominated on the other side by a 1600 m. crest on the range on which the higher camps of this series were situated. Swampy in parts, and drained by a considerable stream named Araucaria Creek for stands of *Araucaria* ... that occurred on its lower course, the valley bottom broadened to approximately 0.5 km. above the camp. Below camp the mountains gradually closed in and the creek became a succession of rapids, pools, and small waterfalls.... Rain-forests filled the valley bottom and extended up the slopes to *Nothofagus*-forest on both sides. But on the south slope, between 870 m. and 950 m. altitude, some broad ridges, at best poorly drained and in parts swampy, carried a distinctive type of forest dominated by *Agathis*....

Brass' detailed description of local habitats at this station, along with good accompanying photographs (Brass, 1941; pl. 6, fig. 1, and pl. 5, fig. 2; reproduced here as figs. 6 and 7, respectively), provide the ecological context for the collection of the holotype, allowing a glimpse into general forested environments in an area where *M. richardsoni* occurs.

On the northern slopes of the Central Cordillera, *M. richardsoni* occurs at lower elevations than most species of *Pseudohy-*

dromys, New Guinea's other 'moss-mouse' genus (Helgen and Helgen, 2009). If *M. richardsoni* is wholly or largely confined to elevations of 1500 m and lower, it is likely to co-occur locally with only one species of *Pseudohydromys*, *P. ellermani* (Laurie and Hill, 1954), a Central Ranges endemic that has an elevational "floor" of 1400 m and occurs across most of the length of the Cordillera, from the Snow Mountains to the Wau Valley (Helgen, 2005a; Helgen and Helgen, 2009). We suspect that *M. richardsoni* may also co-occur with *Pseudohydromys musseri* in the North Coast Range, where both species are recorded, as the sole known trapping site for *musseri* (situated at 1350 m) falls within the recorded elevational range of *richardsoni* (i.e., from near sea level [Oenake Range maxilla] to at least 1500 m along the Central Cordillera).

The total sample of cranial and dental remains from Paleflatu Cave in the Oenake Range represents several thousand individuals and includes numerous examples of another similarly tiny-bodied murine rodent, *Lorentzimys nouhuysi* Jentink, 1911 (K. Aplin, personal obs.). Unless some aspect of the biology of *M. richardsoni* (e.g., diurnality, though the minuscule eyes and dark gray pelage of the species of *Microhydromys* suggest nocturnal habits) makes it largely immune to owl predation, its sparse representation in the Paleflatu assemblage is best explained by natural rarity in those habitats within the hunting range of the owls in the area (which would include various lowland and limestone hill forests, up to local topographic highs of approximately 500 m).

All other hydromyins that have been studied to date are largely or partly animalivorous (e.g., Woollard et al., 1978; Menzies and Dennis, 1979; Voss, 1988; Jackson and Woolley, 1993; Flannery, 1995; Helgen, 2005b; Musser et al., 2008; Helgen and Helgen, 2009), and we suspect the same is true for the species of *Microhydromys*. Their solid orthodont incisors, tiny molars, somewhat shrewlike appearance, and terrestrial habits suggest to us a lifestyle spent preying upon invertebrates in soil and leaf litter on the forest floor in New Guinea hill forests.

Microhydromys argenteus, new species

HOLOTYPE: BBM-NG 60202, adult male, study skin with accompanying skull and

mandible in excellent condition (figs. 2, 3), from Sirinumu Dam, 550 m, on the Sogeri Plateau (Central Province, Papua New Guinea), collected 28 October 1968 by M. Nadchatram.

REFERRED SPECIMENS: AM M14166, adult female, flat skin with accompanying skull and mandible in good condition, from Mt. Sisa (= Mt. Haliago), 1450 m (Southern Highlands Province, Papua New Guinea), collected 18 September 1979 by P. Dwyer (original number E1005). Dwyer (1990: 210) identified this specimen as "*Microhydromys cf. richardsoni*." The skull and skin of AM M14166 were figured by Flannery (1989: 217–218).

UPNG 4310, adult male (fig. 4), preserved whole in fluid (fixed in 10% formalin and preserved in 70% ethanol), from 10 km NE of the village of Faia on the Darai Plateau (7.130°S, 143.611°E, Gulf Province, Papua New Guinea; figs. 1, 9), 380 m, collected 26 July 2003 by T. Leary and M. Pennay (original number DAR22).

DIAGNOSIS: *Microhydromys argenteus* differs externally from *M. richardsoni* in having paler, uniformly gray-brown pelage, both dorsally and ventrally (darker grayish-black fur, above and below, sometimes with white flecking on the belly, in *M. richardsoni*: fig. 2); a proportionally shorter tail, measuring 91%–95% of head-body length (101%–111% of head-body length in *M. richardsoni*: table 1); a long pale terminal tip, measuring at least one-third of total tail length, with pale mottling extending beyond, to at least to the midpoint of the tail, on both the dorsal and ventral surfaces (versus a shorter discrete pale tail tip, less than one-quarter of tail length and without mottling or with less extensive mottling in *M. richardsoni*); and slightly larger hind feet and pinnae (table 1). Compared to *M. richardsoni*, the skull of *M. argenteus* has proportionally wider zygomata, broader incisors, slightly narrower molars, shorter incisive foramina, and larger auditory bullae.

ETYMOLOGY: The epithet *argenteus* references the grayish pelage of this species, which allows for its immediate discrimination from the blackish *M. richardsoni*. We recommend the English common name "southern groove-toothed moss-mouse". Leary (2004) noted that the local name *Mirin* is used for this

species in the Kasere language on the Darai Plateau. According to Dwyer (1990), Etolo speakers from Mt. Sisa used the name *Ebele Ebele Mano* for this species, a designation that indicated their impression that it was a juvenile specimen of a larger murid—"i.e., the animal was said to be a baby rat; the intention may have been that it was a baby *Melomys*" (Dwyer, 1990: 210).

DISTRIBUTION: *Microhydromys argenteus* has been recorded from three localities along the southern slopes of the Central Cordillera in south-central and southeastern Papua New Guinea (Southern Highlands, Gulf, and Central Provinces), situated from 380 to 1450 m (fig. 1). The mean elevation of these three trapping sites is 793 m. Though rarely collected, the available captures indicate that it is likely to be widespread in hill forest and lower montane habitats along the southern margin of the Cordillera.

DESCRIPTION: *Microhydromys argenteus* is a tiny, grayish-brown mouse with very small eyes. It has a gray tail, slightly shorter than the head and body length, bearing a prominent white distal tail tip. The pelage is soft and very short, measuring 4–5 mm on the midback, as in *M. richardsoni* (Tate, 1951). The coloration of the body is distinctly paler both above and below than the more blackish fur of *M. richardsoni*. The dorsal pelage is pale gray, with pure gray fur bases strongly tipped with brown tones. The venter (from lower lips to tail, including the underside of the limbs) is paler and less brownish, uniformly colored apart from a barely indicated thin whitish line on the midbreast in the holotype. The tail, proportionally shorter than in *M. richardsoni* (table 1), is gray proximally (blackish in *M. richardsoni*), with a long distal white tail tip one-third to one-half as long as the tail, sometimes accompanied by further mottling above or below (versus a short, discrete white tail tip about one-quarter of total tail length in extent in *M. richardsoni*). There are 17 tail scales per cm in the midsection of the tail, compared to 15–16 in *M. richardsoni*. The dorsal surfaces of the manus and pes are pigmented pale and covered in very short white hairs (compared to short dark hairs in *M. richardsoni*, which thus has darker feet). The hind feet average longer than in *M.*



Fig. 9. Lowland rain forest on the Darai Plateau, one of the three trapping sites for *M. argenteus* (UPNG 4310). Photograph by Allen Allison.

richardsoni (table 1) and appear broader in direct comparisons of skins. Judging from the few available specimens, the ear averages slightly larger than in *M. argenteus* (table 1), and is paler gray than in *M. richardsoni*. The few available body weights suggest that *M. argenteus* is a slightly heavier mouse than *M. richardsoni*.

As previously discussed by Flannery (1989), the skulls of the two species of *Microhydromys* are very similar (fig. 3), and detailed comparisons are rendered challenging by the limited material in collections. Only three skulls of *M. richardsoni* are available in world museums, and in two of these the braincase is broken posteriorly by characteristic snap-trap damage. Similarly, only two intact skulls of *M. argenteus* are yet available. Nevertheless, several compelling craniodental distinctions are apparent in this material, which comple-

ment the clear-cut external distinctions that characterize these taxa. The two species of *Microhydromys* are more or less equivalent in overall skull size, with *M. argenteus* averaging only slightly larger (table 1). This similarity in cranial size renders certain proportional differences between the species obvious. The zygomata are more robustly expanded in *M. argenteus* than in *M. richardsoni* (fig. 3, table 1). *Microhydromys argenteus* has larger auditory bullae than *M. richardsoni*, a difference perhaps better appreciated in direct comparisons (fig. 3) than in tabulated measurements (table 1). Compared to *M. richardsoni*, the incisors are more robust in *M. argenteus*, though the molars average a touch smaller. In *Microhydromys argenteus* the nasals average longer than in *M. richardsoni*, though the incisive foramina are slightly shorter (table 1).

NATURAL HISTORY: According to its label, the holotype of *Microhydromys argenteus* was snap-trapped in “secondary forest – eucalypt savannah” on the Sogeri Plateau, an interesting indication that this species is not confined to mature forest formations (Flannery, 1995).

The specimen of *M. argenteus* from Mt. Sisa was live-trapped (in an Elliot/Sherman trap) by Dwyer on the “Magidobo grid” (Dwyer, field notes), a locality described as “primary forest with some tree fall dating from a storm two years before” (Dwyer, 1984: 30). The Magidobo grid was trapped by Dwyer for three or four consecutive nights on 11 occasions between February 1979 and February 1980, with a total of 80 traps set per night (equal numbers of wire mesh and Elliot type traps, “nearly always baited with sweet potato”; *ibid.*). No other moss-mice were collected at the site, which was revisited by Aplin in 1985 and characterized as typical lower montane forest (K. Aplin, field notes). Only one other moss-mouse, *Pseudohydromys sandrae* Helgen and Helgen, 2009, is recorded from Mt Sisa (a distinctive species known only from the holotype, obtained by Dwyer at around 850 m in hill forest; Helgen and Helgen, 2009). Syntopy between this species and *M. argenteus* seems likely but remains to be demonstrated. Further information on Mt Sisa and its various forest communities was provided by Dwyer (1990).

The Darai Plateau (lying within Southern Highlands, Western, and Gulf provinces of Papua New Guinea) is an extensive limestone plateau with karst corridors and elevated flat-topped limestone surfaces of very low relief that runs from immediately south of Mt Bosavi, almost to the Gulf of Papua (Bellamy and McAlpine, 1995). It lies on the western edge of the Kikori Integrated Conservation and Development Project area. The associated outlying karst ridges range from 300 to 700 m above sea level. The area is replete with steep karst pinnacles and dolines that are undermined by karst caves that result in numerous sinkholes. Vegetation on the plateau has been described as lowland hill forest with polygonal karst geology and adverse soil conditions (Paijmans, 1976). Recently, Gebia and Balun (2004) characterized the vegetation of the region in greater

detail. The vegetation at the Darai site is possibly the most diverse site ever surveyed in PNG, with 368 and 389 species recorded in the two 0.2 hectare transect belts surveyed by Gebia and Balun (2004). The forest structure at the Darai site was distinctly layered, comprising emergents, upper canopy, subcanopy and shrub layers. Most emergents and many canopy trees had wide crowns with tall straight boles. Emergents were between 40 and 45 m in height, whilst the upper canopy was generally 30–35 m high. The main emergents were *Pterocymbium beccarii*, *Sloanea forbesii*, and *Terminalia complanta*. Upper canopy species included *Elaeocarpus nouhuysii*, *Dysoxylum* spp., *Cryptocarya* spp., and *Chisocheton* spp. Subcanopy species included *Myristica fatua* var. *papuana*, *Haplolobus floribundus*, *Canarium* sp., *Pouteria* sp., and *Palaquium* sp. The lower story was extremely dense and primarily composed of *Ficus* spp., *Syzygium* spp., and species of Annonaceae, Meliaceae, and Rubiaceae. The forest floor vegetation was dense and consisted of species of Zingiberaceae, Urticaceae, and Gesneriaceae. The specimen of *Microhydromys argenteus* from the Darai Plateau was caught in an Elliot trap, baited with canned fish, in primary forest. The trap was placed in a drainage line that flowed during heavy rain (although water dissipated through limestone crevices soon after the rain ceased). This specimen was captured alive in the trap, but died within two hours of being brought to the camp. The area where this specimen was captured was situated at an elevation of approximately 380 m (figs. 1, 9). The village of Faia, on the Hawoi River, is located approximately 10 km to the south west from the trapping site. The trapping site is on a walking route between Faia and the village of Kiam, and is periodically used for hunting by local landowners. One of us (TL) has surveyed small mammals with similar trapping protocols at nine other sites situated in similar habitats and elevations in Gulf and Southern Highlands provinces over the past decade (e.g., Leary and Seri, 1997; Leary and Mamu, 2004), but the paratype from the Darai Plateau is the only specimen of *Microhydromys* encountered to date. This provides a further indication that this species is naturally rare and/or difficult to trap.

The three documented trapping localities for *M. argenteus* (Sogeri Plateau, Mt. Sisa, and the Darai Plateau) indicate that the species probably has a relatively broad distribution in the foothills and lower montane forests along the southern slopes of the Central Cordillera, and is likely to occur in similar habitats across the region where trapping efforts have been less intensive. Mammal species with similar recorded global geographic and elevational distributions to *M. argenteus* include the dasyurid *Myoictis leucura* Woolley, 2005; the macropodids *Dendrolagus spadix* Troughton and Le Souef, 1936 and *Dorcopsulus macleayi* (Miklouho-Maclay, 1885); the murine *Leptomys elegans* Thomas, 1897; the hipposiderid *Hipposideros muscinus* (Thomas and Doria, 1886); and the emballonurid *Emballonura furax* Thomas, 1911 (Flannery, 1995; Flannery et al., 1996; Helgen, 2007; Musser et al., 2008; Woolley, 2005). The southern foothill forests of the Cordillera are generally less well explored for mammals in the west (in Indonesian New Guinea) than they are in the east (in Papua New Guinea). Although many of these species, like *M. argenteus*, have only been recorded in Papua New Guinea to date, we suspect that this entire suite of southern hill forest taxa may have a broader actual distribution that extends also into appropriate habitats in southern Indonesian New Guinea (Helgen, 2007).

DISCUSSION

Our description of *Microhydromys argenteus* appears in the midst of a resurgence of interest by a number of workers in the characterization of species boundaries in Melanesian mammals (Aplin et al., in review; Helgen, 2003, 2005a, 2005b, 2005c; Helgen and Flannery, 2004a, 2004b; Helgen and Helgen, 2009; Musser et al., 2008; Musser and Lunde, 2009; Woolley, 2005). Collectively, these studies abundantly demonstrate the as yet very incomplete state of knowledge of mammalian taxonomic diversity across the entire region and across all groups of mammals.

Care must be exercised when undertaking a taxonomic revision on the basis of small numbers of specimens, especially when they

are drawn from within a large geographic area and across a significant altitudinal range. At the same time, to ignore significant morphological variation because sample sizes are not conducive to quantitative analysis carries the risk of seriously underestimating biodiversity, particularly in a region like New Guinea where so many taxa remain poorly represented in museum collections. In such cases, a balanced and common sense approach is called for, using morphological variation in better-known representatives of the same group as a general yardstick of acceptable species limits, and using general biogeographic patterns to provide an a priori likelihood of taxic diversity, i.e., does a multispecies hypothesis have any biogeographic precedent?

As documented here, the six available modern specimens of *Microhydromys* sort into two clear morphological samples. One series of three specimens comes from localities north of the Central Cordillera, while the other series of three comes from localities south of the Cordillera. The two groups are characterized by pervasive morphological differences that affect almost all aspects of external and craniodental anatomy. As the two taxa are very similar in body size, the differences are clearly not allometric in nature, nor are they likely to be phenotypic expressions of adaptation to different bioclimatic contexts, as all specimens come from within a similar range of elevations and habitats. Rather, the morphological contrasts between the two series of *Microhydromys* are similar to those documented between sibling pairs within the other New Guinea 'moss-mouse' genus, *Pseudohydromys*, for which a greater range of comparative material is available (Helgen and Helgen, 2009). Contrasts of similar character and magnitude likewise discriminate different species of *Mus* Linnaeus, 1758, a genus of equivalent body size, in Eurasia (Macholán, 1996a, 1996b, 2001).

New Guinea's expansive Central Cordillera (also called the Central Range or Central Dividing Ranges) consists of many high mountain ranges that extend across the mid-body of the island of New Guinea in an east-west orientation, from the Weyland Range (on the western margin of the Snow Mountains) in the west to the Maneau Range (at the eastern

tip of the Owen Stanley Ranges) in the east. Nowhere along this expanse (which is more than 1600 km long and up to 200 km broad) is there a mountain pass lower than 1000 m, such that the high, long, and broad Central Cordillera is one of the most impressive physical aspects of the island and is hypothesized to be one of the most important biogeographic barriers to dispersal in Melanesia, especially for widespread lowland-adapted lineages (McMichael and Hiscock, 1958; Pratt, 1982; Stattersfield et al., 199; Heads, 2001; Beebe and Cooper, 2002). In addition to *Microhydromys*, many other groups of vertebrates inhabiting the lowlands of New Guinea show examples of sister species pairs or major intraspecific phylogeographic partitions divided by the Central Cordillera (Flannery, 1992, 1995; Aplin, 1998; Austin, 2000; Dumbacher and Fleischer, 2001; Dumbacher et al., 2003; Rawlings and Donnellan, 2003; Helgen, 2007; Norman et al., 2007). Among terrestrial mammals, examples include the lowland cuscuses (*Phalanger orientalis* (Pallas, 1766) in the north, *P. intercastellanus* Thomas, 1895 and *P. mimicus* Thomas, 1922 in the south), the forest wallabies (*Dorcopsis hageni* Heller, 1897 in the north, *D. luctuosa* (D'Alberty, 1874) in the south) and pademelons (*Thylogale browni* (Ramsay, 1877) in the north, *T. brunii* (Schreber, 1778) in the south), and lowland tree rats (*Rattus praetor* (Thomas, 1888) in the north, *R. leucopus* (Gray, 1867) in the south). Pratt (1982) speculated that lowland New Guinean birds speciated in response to the periodic contraction of lowland rain forests (and their associated faunas) into isolated "refugia" during cold, dry glacial cycles. Whether this, or any other common biogeographic scenario, underpins the wider pattern requires careful testing using phylogeographic methods coupled with analysis of available late Quaternary fossil assemblages (e.g., Aplin and Pasveer, 2005). For the present, the important point is that our biogeographic hypothesis for *Microhydromys*, with separate species present on either side of the Central Cordillera, is amply supported by examples from a diverse group of other organisms.

For these reasons, and additionally because we judge it unlikely that any significant

number of additional specimens of this rare genus will be forthcoming soon, we do not hesitate to describe *M. argenteus* as a new and distinctive species. Future collecting efforts, especially through targeted efforts such as extensive pitfall trapping in New Guinean foothill forests, will hopefully provide new material to test our hypothesis that *Microhydromys* from north and south of the Cordillera represent distinctive species, and will very likely uncover additional species in this ecologically cryptic genus.

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